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MATHEMATICS AND BACTERIOLOGY.—*On the dilution method of counting bacteria.*[1] P. V. WELLS and W. F. WELLS. (Communicated by S. W. Stratton.)

The dilution method of counting the number of bacteria in water is an example of the use of a geometric scale when the variations are so large that an arithmetic scale is cumbersome. We shall investigate briefly the theoretical basis of this method, with a view to the standardization of the experimental procedure, and shall show that its results have a remarkably simple interpretation.

FUNDAMENTAL THEOREM

Consider a "universe" containing A cc. of water, and B bacteria. If a sample of α cc. is examined, the chances of finding n, $n-1, \ldots . 2$, 1, 0 bacteria, respectively, in the sample are given by the terms of the hypergeometric series

$$\frac{B(B-1)\ldots(B-n+1)}{N(N-1)\ldots(N-n+1)}\left[1+n\frac{W}{B-n+1}+\frac{n(n-1)}{2!}\frac{W(W-1)}{(B-n+1)(B-n+2)}+\ldots.\right] \quad (1)$$

where the water is conceived as composed of W "particles," giving the total "population" $N \equiv B+W$, and the sample contains n particles. Each particle, whether bacterium or water, is assumed to have an equal chance of being sampled. The general term, for the probability of finding C bacteria in the sample is

$$P_C = \frac{B(B-1)\ldots.(B-n+1)}{N(N-1)\ldots.(N-n+1)}\left[\frac{n(n-1)\ldots.(n-C+1)}{C!}\frac{W(W-1)\ldots.(W-n+C+1)}{(B-n+1)(B-n+2)\ldots.(B-C)}\right] \quad (2)$$

But since the population N is arbitrary, this result is of little use as it stands.

Taking the population N as infinite, and n as extremely large, but small compared with N, and placing $X \equiv B/A$ as the number of bac-

[1] Received April 29, 1921.

teria per cc., we have $B/N = \alpha X/n$. Hence equation (2) reduces to

$$P_C = \frac{(\alpha X)^C}{C!} \exp(-\alpha X) * \tag{3}$$

which is the fundamental expression for the probability P_C of finding C bacteria in an α cc. sample of water containing X bacteria per cc. The sample usually taken is $\alpha = 1$ cc. From the form of the expression we have

$$\sum_0^\infty C(P_C) = 1 \tag{4}$$

as it should, to represent probability. The probability P_0 of a negative result, on plating out, is

$$P_0 = \exp(-\alpha X) \tag{5}$$

and of a positive result is $1 - P_0$. This reduces to McCrady's[2] result when $\alpha X = 1$, namely $1 - P_0 = 1 - 1/e = 0.63$.

As there has been some misunderstanding of McCrady's work, perhaps due partly to the form in which it was expressed, a few remarks on the theory here given may be appropriate. The only assumptions are: (1) that in a large number of samples of α cc. each, the bacterium considered is on the whole as often in one of the samples as in another (random distribution), and (2) that the presence of one bacterium in a sample does not affect the chances of the others being there (independent probabilities). These assumptions can hardly be doubted in this particular case, because one bacterium occupies about 10^{-12} cc., so that one million per cc. would occupy only one millionth of the volume. From studies of Brownian particles it is known that there are considerable fluctuations in density.

Now suppose the samples are diluted, β cc. in D cc. of water, then the probability of finding C bacteria in α cc. of the diluted sample is, from (3)

$$P_C = \frac{z^C}{C!} \exp.(-z) \tag{6}$$

where

$$z \equiv \alpha\beta \frac{X}{D}$$

* $P_C = \frac{(\alpha X)^C}{C!} e^{-\alpha X}$

[2] H. H. McCRADY. Journ. Infectious Diseases 17: 183. 1915.

As a function of z, this equation is a special case of Pearson's Type III frequency curve, and the mode M_z, or most probable value of z is simply $M_z = C$.

"PER CENT NEGATIVE" METHOD

The quantities α and β are usually taken as 1 cc. ($\alpha = \beta = 1$). The probability of a negative result (no bacteria) in the diluted sample is simply the negative exponential

$$P_0 = \exp.\left(-\frac{X}{D}\right) \tag{7}$$

This is the frequency curve of the negative plates in dilutions D. The mode ($M_D = \infty$), or most probable value of the negative dilution D is infinite, as it should be. The fraction of negative plates in dilution D is P_0, and the percentage of negative plates 100 P_0, when the number of samples taken is sufficiently large to overcome the fluctuations of sampling, and when there is no constant error in the experimental procedure.

In practice the sample (1 cc.) is diluted in the definite dilutions $D = 10$, 100, 1000, etc., cc. of water, and P_0 observed. In order to compute X from these results, place in (7)

$$E \equiv \ln\left(\frac{1}{P_0}\right) = \frac{X}{D} \tag{8}$$

Then

$$x = d + e \tag{9}$$

Where

$$\left.\begin{aligned} x &\equiv \log X \\ d &\equiv \log D \\ e &\equiv \log E \end{aligned}\right\} \tag{10}$$

The arithmetic means $\bar{d}$ and $\bar{e}$ are therefore related by the simple expression

$$x = \bar{d} + \bar{e} \tag{11}$$

and the number of bacteria per cc. X is given by the product of the geometric means

$$X = G_D G_E \tag{12}$$

Where

$$\left.\begin{aligned} \bar{d} &\equiv \log G_D \\ \bar{e} &\equiv \log G_E \end{aligned}\right\} \tag{13}$$

The "per cent negative" method requires for convenient application a table giving e in terms of P_0, as in table 1.

It is evident from the magnitudes in the second column of table 1

TABLE 1

Per cent Negative $100\,P_0$	Correction e
5	0.48
10	0.36
15	0.28
20	0.21
25	0.14
30	0.08
35	0.02
36.8	0
40	0.96–1
45	0.90–1
50	0.84–1
55	0.78–1
60	0.71–1
65	0.63–1
70	0.55–1
75	0.46–1
80	0.35–1
85	0.21–1
90	0.02–1

that the arithmetic mean $\bar{e}$ in any actual case will be merely a correction to be applied to the "average log dilution negative" $\bar{d}$. The number of bacteria per cc., X, is therefore roughly equal to the geometric mean G_D of the numbers of cc. (D) into which the sample (1cc.) is diluted. Its precise value is given by (12) which is used in the form (11).

The computation of the "log count" (x) is very simple. The dilutions are $D=10$, 100, 1000, 10,000, etc., and the corresponding "log dilutions" are $d=1$, 2, 3, 4, etc.; only those dilutions are chosen for which the "per cent negative" ($100P_0$) is between 5 and 90 per cent. The values of e are taken from table 1, and the sum $(d+e)$ recorded. The simple average of these figures gives x. The antilogarithm of x is the number of bacteria per cc. (X). The following examples illustrate the method.

Example 1

(20 samples, 3 negative in $D=10$ cc., 13 in 100 cc., and all in 1000 cc.)

d	Per cent Neg.	$d+e$
1	20	1.21
2	65	1.63
		$x=1.42$

$X=26$ bacteria per cc.

Example 2

(20 samples, 11 negative in 10,000 cc., all negative in 100,000 cc.)

d	Per cent Neg.	$d+e$
4	55	$x=3.78$

$X=6\times10^3=6{,}000$ bacteria per cc.

To determine P_0 with precision, more samples must be taken at each dilution than is practicable for a single specimen of water, but the method is very useful where many bottles of water are collected, or where the samples represent a seasonal distribution. The use of the geometric mean in such cases is justified only by the type of such frequency distributions. This point will be considered in a subsequent paper.

METHOD OF BACTERIAL COUNTS

No information is gained in the "per cent negative" method from the number of colonies found on the positive plates. Returning to the fundamental equation (6), the probability of finding C bacteria in the diluted sample is

$$P_C=\frac{z^C}{C!}\exp.(-z) \tag{6}$$

Now the bacterial counts are usually fairly large ($C>10$). In this case Stirling's formula gives

$$C!=C^C\sqrt{2\pi C}\exp.(-C) \tag{14}$$

Comparing (6) and (14),

$$P_C=\frac{1}{\sqrt{2\pi C}}\left(\frac{z}{C}\right)^C\exp.(C-z) \tag{15}$$

This is the frequency curve of bacterial counts of a given sample (at a fixed dilution). The mode (M_C), or most probable value, of C is given by the condition

$$\frac{1}{P}\frac{dP}{dC}=\ln\frac{z}{C}-\frac{1}{2C}=0\ (\text{when } C=M_C) \tag{16}$$

Neglecting $\frac{1}{2C}$ compared with $\ln C$, involving an error of 2 per cent when $C=10$, and less for larger values, we have

$$M_C=z=\alpha\beta\frac{X}{D}\quad(C>10) \tag{17}$$

That is, when $\alpha=\beta=1$, the number of bacteria per cc. (X) is simply the product of the dilution D and the mode M_C of the frequency dis-

tribution of bacterial counts C as would be guessed from "common sense."

The frequency distribution (6) is mathematically very complicated. Its graph, represented in figure 1 for the values $z=10$ and 100 bacteria per cc., shows it to be nearly symmetrical about the mode, the

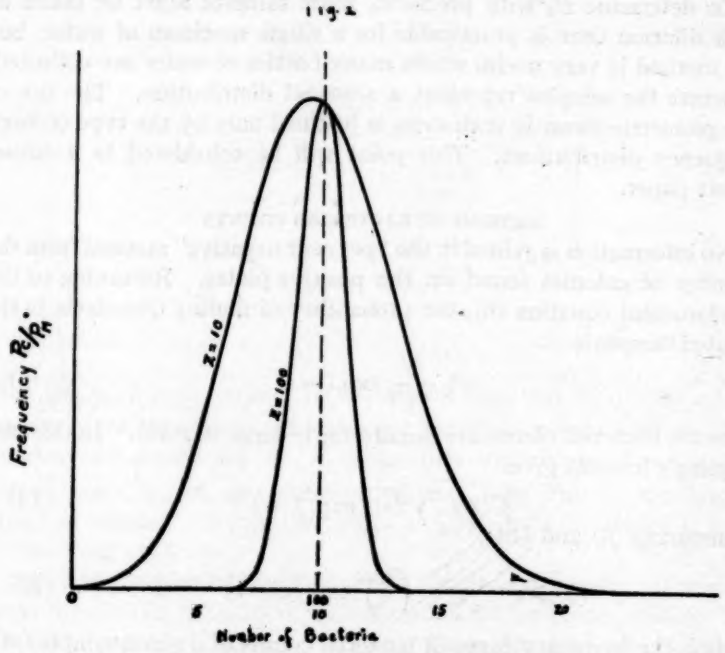

Fig. 1.—Graph of frequency distribution.

maximum becoming very accentuated as z increases. This is obvious from the variability of the curve, computed by Pearson's method of moments, and given in table 2 together with the other constants.

Thus the curve possesses the remarkable property that although it is unsymmetrical, the mode and the arithmetic mean coincide within the errors of the computation. The geometric mean is of course slightly smaller, but either mean is quite close enough for practical use. Replacing the mode in (17) by the arithmetic mean $(\overline{C})$, we have

$$X=\overline{DC} \qquad (18)$$

so that the number of bacteria per cc. is calculated simply.

Representing the mode by the geometric mean (G_C), equation (17) becomes

$$X = G_D G_C \tag{19}$$

where G_D is the geometric mean of the dilution (D). Changing variables to the logarithm, this gives

$$x = \bar{d} + \bar{c} \tag{20}$$

as the relation between the arithmetic means of the logarithms, and

$$\left.\begin{aligned} x &\equiv \log X \\ \bar{d} &\equiv \log G_D \\ \bar{c} &\equiv \log G_C \end{aligned}\right\} \tag{21}$$

TABLE 2

CONSTANTS OF BACTERIAL FREQUENCY

Number of Bacteria per cc. (s)	10	100
Arithmetic Mean Bacterial Count ($\overline{C}$)	9.995	100.001
Geometric Mean " "(G_C)	9.54	99.76
Standard Deviation (σ)	3.02	9.55
Variability ($100\frac{\sigma}{\overline{C}}$)	30 per cent	9.6 per cent

The logarithms can be read conveniently from the two-place table. (Tab. 3).

TABLE 3

TWO-PLACE LOGARITHMS

	0	1	2	3	4	5	6	7	8	9
1	00	04	08	11	15	18	20	23	26	28
2	30	32	34	36	38	40	42	43	45	46
3	48	49	51	52	53	54	56	57	58	59
4	60	61	62	63	64	65	66	67	68	69
5	70	71	72	72	73	74	75	76	76	77
6	78	79	79	80	81	81	82	83	83	84
7	85	85	86	86	87	88	88	89	89	90
8	90	91	91	92	92	93	93	94	94	95
9	95	96	96	97	97	98	98	99	99	00

To illustrate the computation, an example is worked out. (Example 3.)

In any actual experiment the discrepancy between the two means is almost certainly due to experimental errors, and not to theoretical fluctuations of sampling. These errors are largest in the largest dilutions. The geometric mean is less affected by large errors in excess than is the arithmetic mean. On the other hand negative plates must be ignored, for a single one would make the geometric mean vanish. The question of what mean to use in this work, however, has little

theoretical importance. It is in space and time distributions that large variations and skewness may arise, and then the means differ significantly. In many such cases the geometric mean is more probable than the arithmetic mean, as will be shown in a later paper.

Example 3

EXPLANATORY FORM

Dilution	Bacterial count						
D	C	DC	Deviation	d log D	c log C	$d+c$	Deviation
1 cc.	Too many to count.						
10 cc.	(200)						
100 cc.	130	13,000	29,000	2	2.11	4.11	0.40
	190	19,000	23		2.28	4.28	.23
1000 cc.	82	82,000	40	3	1.91	4.91	.40
	53	53,000	11		1.72	4.72	.21
10,000 cc.	None						
Sums		167,000	103,000	5	8.02	18.02	1.24
Arith. means		42,000 ±	13,000	2.5	2.01	4.51 ±	.16

Arith. mean of logs $\equiv x = 4.51$

Geometric mean $\equiv$ antilog $x = 32{,}000 \pm 14{,}000$

Number of bacteria per cc.

Geom. mean $\equiv G_X \equiv G_D\, G_C =$ 32,000 ± 14,000 $= (3.2 \pm 1.4) \times 10^4$

Arith. mean $\equiv \overline{X} \equiv \overline{DC} =$ 42,000 ± 13,000 $= (4.2 \pm 1.3) \times 10^4$

ACTUAL ROUTINE FORM

DC	d	$d+c$	Dev.
13,000	2	4.11	40
19		.28	23
82	3	.91	40
53		.72	21
4 | 167		4 | 202	124

$\overline{DC} = 42{,}000 \pm 14{,}000$. $x = 4.51 \pm 0.16$

$G_X = 32{,}000$

It should be emphasized that the logarithm itself furnishes a most convenient scale for the expression of results in bacteriology. Thus, instead of bothering to find the antilogarithm of x, this value itself can be used; $x = 3.67$ means quite as much as $X = 4.7 \times 10^3 = 4700$, when equally familiar, and it is much more convenient for very large numbers, as well as for graphical work. Moreover, the significant changes

are those in x, not X, for in bacterial phenomena the population must be taken into account. The logarithm of the number of bacteria, and not the number itself, should therefore be used for routine purposes.

SUMMARY

The chance (P_C) of finding C bacteria in α cc. of water containing X bacteria per cc. is

$$P_C = \frac{(\alpha X)^C}{C!} \text{ exp. } (-\alpha X)$$

This theorem is applied to the "per cent negative" (100 P_0) method of counting bacteria and to the method of counting positive plates.

It is shown that the variability in samples containing more than ten bacteria is small, so that differences between the arithmetic and geometric means cannot be due to fluctuations of sampling.

The extreme variability usually found in bacteriology is due to differences of locality and time. In any case where the data vary very widely, a few very large values, representing perhaps less than one per cent of the results, may double the value of the arithmetic mean; their effect upon the geometric mean is but slight. This renders the arithmetic mean practically valueless.

Bacteriological frequency distributions usually possess not only wide variability, but positive skewness. In such cases the geometric mean is more probable than the arithmetic mean, but the most important reason for preferring the geometric mean is its stability as an average.

PHYSICS.—*Soft characteristic X-rays from arcs in gases and vapors.*[1]

F. L. MOHLER and PAUL D. FOOTE, Bureau of Standards.

If an electron current is maintained by a potential V between a hot cathode and anode in a vapor at low pressure, then as V is increased successive changes occur in the spectrum excited by electron impact. The highest frequency ν of each additional group of lines is related to the least potential required to excite the group by the quantum equation $Ve = h\nu$.

The authors have studied the stages in the discharge by measuring the photo-electric effect of the radiation on two other electrodes entirely shielded from ions produced in the arc. This photo-electric current plotted as a function of the exciting voltage shows nearly a linear relation with changes of slope at critical potentials. In this

[1] Received June 15, 1921.

manner potentials have been found which are determined by the limiting frequency of the softest X-ray series of a number of elements.

Table 1 gives the observed potentials, and the corresponding wave lengths for these X-rays. Carbon was studied in the compounds CO, CO_2, C_2H_4 and CCl_4. The latter compound also gave the chlorine points. The nitrogen point was obtained from air and the other points from the various elements at temperatures giving suitable vapor pressures.

TABLE 1. Soft X-rays from Low-Voltage Arcs.

Element	Observed potentials in volts		λ in Å		Computed λ	Remarks
	a	*b*	*a*	*b*	L_a	
Sodium	35.	17.	353.	726.		
Magnesium	46.	34.	268.	363.	263.	
Phosphorus	126.	99.	98.0	126.	92.2	
Sulphur	152.	121.	81.2	102.	77.2	
Chlorine	197.	156.	62.7	79.1	61.9	
Carbon	272.		45.4			} *K* series limits
Nitrogen	375.		32.9			
Potassium	23.	20.	536.	617.		*M* series limits

The limits L_a of the L series for light elements, computed from X-ray spectral data by the relation $L_a = K_a - K_\alpha$, are included in table 1. A plot of $\sqrt{1/\lambda}$ against atomic number shows that both the observed (column *a*) and computed points from magnesium to chlorine fall on the same straight line within the probable observational error. The points *b* for these elements lie on a nearly parallel line. They indicate a new X-ray series of feeble intensity. The value of L_a for sodium falls above the extrapolated straight line but is consistent with Millikan's recent observation of the L_a lines as $\lambda = 372$ and $376A$. The K limits found for carbon and nitrogen fall close to the extrapolated K_a line. The carbon point is in fair agreement with the value $\lambda = 42.6\ A$ found by Kurth[2] who observed the radiation from a solid carbon anode. Theories of atomic structure indicate that the potassium points must be related to the M series.

The above preliminary results emphasize the value of this method of studying radiations in the region between the range of the vacuum spectroscope and the X-ray crystal spectrometer.

[2] Abstract in Phys. Rev. 17: 528. 1921.

TERRESTRIAL MAGNETISM.—*The bearing of the earth's size upon changes in its magnetization.*[1] W. F. G. SWANN, University of Minnesota.

H. Lamb[2] has shown that if a system of currents is started in a sphere of the size of the earth, endowed with a conductivity equal to that of copper at normal temperature, a period of ten million years will elapse before the magnetic field becomes reduced to 1/e of its original value as a result of the decay of the currents. The physical reason for this result lies in the very large effect of self induction in a body of the size of the Earth, as compared with the effect of resistance. The purpose of this note is to examine the bearing of this matter upon one or two questions relating to the Earth's magnetism. For the purpose in hand, it is unnecessary to give an exact mathematical analysis, and it will suffice to handle the problem in a way which does not claim more than a determination of the orders of magnitude of the elements involved. Such a simplified procedure serves, moreover, to keep the physical principles more prominently to the fore. In the first place, it may be of interest to verify Lamb's result by this method.

Decay of currents in a sphere.—If B is the average magnetic flux through a section of the sphere containing the equator of the axis of magnetic flux, the e. m. f. around the equator is $\pi a^2 dB/dt$, so that, considering an equatorial ring of unit cross section and specific resistance ρ we have:

$$\pi a^2 \frac{dB}{dt} + 2\pi a \rho i = 0 \qquad (1)$$

where i is the current density.

Now, at each instant, B is *of the order of magnitude* of the magnetic field at the equator of a sphere of radius a due to a current density which may be taken for convenience as proportional to the distance from the axis, and such as to have the value i on the equator. For this case, it may readily be shown[3] that the field at the equator is $4\pi ia/15$, so that, as regards order of magnitude, we may write

$$B = 0.25\pi ia \qquad (2)$$

for a sphere of unit permeability. Substituting in (1) we have, as

[1] Presented at the Washington meeting of the American Physical Society, April 29-30, 1921. Received May 25, 1921.

[2] Quoted by A. Schuster in *A critical examination of the causes of terrestrial magnetism.* Proc. Phys. Soc. Lond. **24**: 124. 1911-1912.

[3] See for example, W. F. G. SWANN, *The Earth's magnetic field*, Phil. Mag. (6) **24**: 97. 1912.

regards order of magnitude:

$$\frac{dB}{dt}+\frac{8\rho}{\pi a^2}B=0$$

leading to:

$$B=B_0\,e^{\frac{-8\rho}{\pi a^2}t}$$

Putting $\rho=1.6\times10^{-6}$ ohm/cm.^{3} $=1.6\times10^3$ e. m. u. for copper, and $a=6.5\times10^8$ cm., as corresponding to the radius of the earth, we readily find that $\pi a^2/8\rho=10^{14}$ seconds; so that, for $B/B_0=1/e$, we have $t=10^{14}$ seconds, that is, 3×10^6 years, which, in view of the approximations involved, is in sufficiently good agreement with Lamb's result.

Case of the destruction of a state of permanent magnetization.—It is usually maintained that the Earth cannot be a permanent magnet on account of the high temperature of its interior. It is interesting to observe, however, that if it had been a permanent magnet originally, the destruction of this magnetization would set up induced currents which would tend to perpetuate the field; and, as will appear, the net result would be that, for a body of the Earth's size, and with the conductivity of copper, about three million years would elapse before the field had sunk to a value 1/e of that prevailing before the magnetization was destroyed.

Suppose that B represents the average induction through a great circle of the order of magnitude of the radius of the sphere. Then equation (1) applies as before. Now if $\overline{B}$ is the induction due to the permanent magnetization, then for a sphere of unit permeability, which it will suffice to consider, i is of the order of magnitude obtained by replacing B by $B-\overline{B}$ in equation (2), that is,

$$B-\overline{B}=0.25\pi ia$$

so that, using (1), we have, as regards order of magnitude,

$$\pi a^2\frac{dB}{dt}+8\rho\,(B-\overline{B})=0 \qquad (3)$$

Suppose now that the permanent magnetization $\overline{B}$ decreases according to the law:

$$\overline{B}=\overline{B}_0\,e^{-\alpha t}$$

Then, from (3),

$$\frac{dB}{dt}+\frac{8\rho}{\pi a^2}B=\frac{8\rho}{\pi a^2}\overline{B}_0e^{-\alpha t} \qquad (4)$$

The solution of this equation, subject to $B=\overline{B}_0$ when $t=0$, is:

$$B=\frac{\bar{B}_0}{1-\frac{8\rho}{\pi a^2\alpha}}e^{\frac{-8\rho}{\pi a^2}t}-\frac{\frac{8\rho}{\pi a^2\alpha}\bar{B}_0}{1-\frac{8\rho}{\pi a^2\alpha}}e^{-\alpha t}$$

To fix our ideas, suppose that the permanent magnetization is practically destroyed in a time short compared with $\pi a^2/8\rho$, which, for copper, and for a equal to the radius of the Earth, amounts to 10^{14} seconds. Then $8\rho/\pi a^2\alpha$ is a small quantity, and we have approximately:

$$B=\bar{B}_0 e^{-\frac{8\rho t}{\pi a^2}}$$

so that, even though the permanent magnetization is destroyed rapidly, the order of magnitude of B will still be B_0/e after a lapse of 10^{14} seconds, or three million years.

APPLICATION TO THE SECULAR VARIATION

Such evidence as exists with regard to the secular variation appears to indicate that the magnetic poles describe closed curves about the geographic axis with a period of the order of 500 years. The curve is possibly accompanied by smaller loops, which need not concern us here, however.

Suppose that, as a first approximation, we divide the Earth's magnetization into two uniform magnetizations, one parallel to and one perpendicular to the geographic axis, and regard the latter as rotating, with regard to the earth itself, once in 500 years. We do not know the mechanism of the process; but, it is interesting to inquire as to what would follow by considering it merely as a rotation of a state of permanent magnetization in the above manner. We shall find that the induced currents play a very important part, both as regards their power to almost cancel the effect of the rotating permanent magnetization, and also as regards their influence in producing a lag of the resultant magnetization behind the permanent magnetization.

If D_0 refers to the permanent component of magnetization perpendicular to the geographic axis, then, on considering the case of a meridian circle, we shall have an equation similar to (4), but with $\bar{B}_0e^{-\alpha t}$ replaced by $D_0 \cos 2\pi t/T$, where $2\pi t/T$ represents the angle between the direction of D_0 and the perpendicular to the plane of the meridian circle in question. As regards order of magnitude we thus have:

$$\frac{dB}{dt}+\frac{8\rho}{\pi a^2}B=\frac{8\rho}{\pi a^2}D_0\cos\frac{2\pi t}{T}$$

The complementary function may be neglected after a sufficiently long time, and we shall be left with the particular solution:

$$B=\frac{D_0}{(1+\frac{\pi^4a^4}{16T^2\rho^2})^{1/2}}\cos\left(\frac{2\pi}{T}t-\theta\right)$$

$$\text{where } \tan\theta=\frac{\pi^2a^2}{4\rho T}$$

There is thus a lag, and a reduction of amplitude in the ratio unity to $(1+\pi^4a^4/16T^2\rho^2)^{1/2}$.

If T is of the order of 500 years, and ρ corresponds to copper, this ratio amounts to 0.27×10^{-4}. Thus, if the resulting apparent magnetization perpendicular to the geographic axis is to be at all comparable with the permanent magnetization (or its equivalent[4]) perpendicular to that axis, the internal conductivity of the Earth must be smaller than that of copper at least in the ratio 0.3×10^{-4} to unity. Of course, there is nothing remarkable in this since presumably nobody would wish to consider the conductivity of the Earth's interior as comparable with that of copper; but it is nevertheless of interest to observe that the period of the secular variation has something to say as regards an upper limit to the conductivity in question.

When one pictures the flow of currents left to themselves in a sphere, he is likely, at first sight, to regard resistance as the main influence controlling them. We see, however, that in the case of a large sphere, such currents are more analogous in their behavior to highly frictionless gyroscopes, and the problems of precession, etc., associated with gyroscopic motions naturally invite attention.

The pertinence of the above to problems concerning magnetic fields in sun-spots is obvious.

PETROLOGY.—*Preliminary note on monticellite alnoite from Isle Cadieux, Quebec.*[1] N. L. BOWEN, Geophysical Laboratory, Carnegie Institution of Washington.

The occurrence of alnoite in the vicinity of Montreal, Canada, has been known for some years. The first discovery was made by Adams,[2] and a paper by Harvie[3] describes a number of separate intrusives of this nature. During the past summer Doctor Harvie called to my

[4] We are not limited to the case of a rotating permanent magnetization as the active agency. Thus we might consider a system of e. m. f.'s of unspecified origin, whose effects were to generate currents which would act as the equivalent of the permanent magnetization cited.

[1] Received June 11, 1921.

[2] F. D. ADAMS. Amer. Journ. Sci. (3) 43: 269–279. 1892.

[3] ROBERT HARVIE. *On the origin and relations of the Palaeozoic breccia of the vicinity of Montreal.* Trans. Roy. Soc. Canada. (3) 3: Sect. 4, 249–299. 1909.

attention the fact that some new occurrences had been found in the course of a road-materials survey of the area which involved, in a petrographic way, merely the identification of the rock as alnoite.[4] An examination of one of these occurrences, that at Isle Cadieux, proved it to be of particular interest, and I am greatly indebted to Dr. Harvie and to the Director of the Geological Survey of Canada for the opportunity of making a more detailed study.

The rock is on the whole particularly fresh for a rock of this kind and the paragenesis of its minerals unusually clear. A fuller description will be given in a paper now in course of preparation which embodies also experimental studies designed to throw some light on the mineral relations. In the meantime it was thought desirable to publish a note on the petrography of the rock mass.

The greater part of the rock is a fine-grained dark gray mass in which the individual minerals are not distinguishable in the hand specimen except in the case of large poikilitic biotites that are its principle constituent.

Under the microscope the rock is seen to consist of biotite, olivine, augite, melilite, perovskite, apatite, titaniferous magnetite, and alteration products, largely carbonates. It is therefore a typical alnoite but differs from all alnoites as hitherto described in that it contains two olivines, namely, ordinary chrysolite and also monticellite, the latter usually in amounts considerably in excess of the amount of chrysolite.

Monticellite, biotite, and melilite constitute groundmass minerals and often poikilitically include augite and chrysolite. Plainly a great deal of resorption of augite and chrysolite has occurred, their places being taken by biotite, monticellite and melilite. There is therefore a marked difference between the chrysolite and monticellite in the manner of their occurrence. Not infrequently monticellite forms a reaction rim about chrysolite with the two olivines in optical continuity. In such cases the great difference in birefringence is particularly clear on account of their uniform orientation. In addition to the different mode of occurrence and the greatly inferior birefringence of the monticellite it is further contrasted with the chrysolite in being plainly optically negative, whereas the chrysolite is just upon the border between the positive and negative members of the forsterite-fayalite series and its sign is therefore doubtful.

[4] Geol. Survey Canada, Summary Rept. 1916: 198–206.

Only those distinctive features of the two olivines that are readily seen in thin section are given here. Chemical evidence and more detailed optical measurements are available, but await the final paper in which the characters of the other minerals and variations within the mass will be discussed.

An analysis of one of the freshest specimens has kindly been made by Dr. H. S. Washington and is given in table 1.

TABLE 1.

CHEMICAL ANALYSIS OF MONTICELLITE ALNOITE.

Isle Cadieux, Quebec. H. S. Washington analyst.

SiO_2	33.26	H_2O-	0.09
Al_2O_3	5.90	CO_2	1.10
Fe_2O_3	5.30	TiO_2	2.15
FeO	6.54	P_2O_5	0.76
MgO	26.41	MnO	0.15
CaO	14.47	Cr_2O_3	0.05
Na_2O	1.23	BaO	0.08
K_2O	0.82	SO_3	0.22
H_2O+	1.91		
		Sum	100.44

This specimen was chosen primarily for its freshness and, while not an uncommon facies, is not altogether representative of the usual type. It contains more melilite than biotite and somewhat more chrysolite than monticellite, whereas these conditions are reversed in the average rock of the mass. If the amounts of CO_2 and H_2O be taken as criteria, this is the least altered alnoite that has yet been analyzed.

Monticellite as an igneous rock mineral.—Monticellite, the lime magnesia olivine, has hitherto been supposed to occur only in contact metamorphic rocks. That it can crystallize directly from melts of the appropriate composition has been shown by Ferguson and Merwin.[5] That it has not been found in igneous rocks before is in part due to the fact that natural magmas have usually not been of appropriate composition and it was not present, but it may also be due to the fact that it has, at times, escaped detection even though present. I have examined a series of slides made from specimens from the original Alnö locality. Only one of these is of alnoite (labeled fine-grained alnoite Aldersnäset, Alnö[6]) and in this I find that many of the chrysolite grains are surrounded by rims of monticellite, always in optical

[5] Amer. Journ. Sci. (4) 48: 81–123. 1919.

[6] The specimens are the property of Dr. WASHINGTON and were collected by Dr. HÖGBOM. A duplicate of this collection is in the U. S. Geological Survey Petrographic Reference Collection, where this rock is No. 1044.

continuity. The resorption relation between the two minerals is plain and the monticellite is here again a groundmass mineral, while the chrysolite occurs as resorbed early crystals. It seems not improbable that other related rocks may contain monticellite and they should be examined carefully with this in mind. It should be noted that monticellite is readily altered, apparently even more readily than melilite, and its presence is to be expected only in the freshest material.

Summary.—In this paper monticellite alnoite from Isle Cadieux, Quebec, is described. The rock shows the two olivines chrysolite and monticellite, the latter usually in greater amount. The chrysolite, together with augite, occurs in early formed crystals, while the monticellite, as well as melilite and biotite, occur as groundmass minerals that have attacked and resorbed the chrysolite and augite. Monticellite often forms reaction rims around chrysolite that are in optical continuity with it.

Monticellite alnoite is a newly recognized but not a new rock type, for some of the alnoite of the original type locality is found to hold monticellite showing the same relationships.

ABSTRACTS

Authors of scientific papers are requested to see that abstracts preferably prepared and signed by themselves, are forwarded promptly to the editors. The abstracts should conform in length and general style to those appearing in this issue.

PHYSICS.—*Polarized light in the study of ores and metals.* FRED. E. WRIGHT. Proc. Amer. Phil. Soc. **58:** 401–447. 1919.

In this paper the attempt has been made to present in connected form the electromagnetic theory of the reflection of light from absorbing media, and especially that part of the theory which treats of the reflection phenomena resulting from vertically incident light-waves under the conditions usually encountered in the use of the reflecting or metallographic microscope. Normally incident white light contains, after reflection by an anisotropic substance, a certain amount of plane-polarized light, and this amount increases with the strength of the birefringence and the biabsorption in the crystal plate. The presence of plane-polarized light in natural light can be detected by several different methods, such as are used in determinations of sky polarization. For this purpose Koenigsberger adopted the Savart method with rotating glass compensator. A second and new method is proposed which employs either a single calcite cleavage plate with proper aperture or a small portable Koenig-Martens photometer. This method is more sensitive than the first. Methods of this kind, which are based on differences in intensity of the reflected components of vertically incident light, are fifty or more times less sensitive in the detection of anisotropism than methods based on the phenomena produced by plane-polarized transmitted light-waves.

In case vertically incident, plane-polarized light is used, the difference in amplitude of the reflected components causes a rotation of a plane of polarization, and this can be detected and measured by any one of a number of devices

in common use by petrologists, such as the sensitive-tint quartz plate, the Biot-Soleil sensitive-tint biplate, the Bertrand eyepiece, and the biquartz-wedge plate. Of these, the last is the most sensitive, because in it the sensibility is variable and can be adjusted to meet the conditions of illumination.

In opaque substances the precision attainable by these methods is, in general, small, and the phenomena which can be observed are relatively few and restricted in scope. As a result, one can not expect from the application of polarized light to such substances the harvest of optical data which has been gathered from transparent crystals. F. E. W.

PHYSICS.—*The measurement of the intensity of transmitted and reflected light by polarization photometers.* FRED E. WRIGHT. Journ. Opt. Soc. Amer. **2**: 65–75. 1919. (Geophysical Lab. Papers on Optical Glass, No. 22*a*.)

In this article a brief statement is given of the methods used by the writer during the war period for the measurement of the light transmission of optical glasses and of optical instruments. Several new attachments and improvements on the Koenig-Martens photometer are described; also the method for their use in the practical measurement of the amount of light transmitted and reflected by optical glasses, and of the light transmission of optical instruments. F. E. W.

PHYSICS.—*Polarization photometer prisms.* FRED E. WRIGHT. Journ. Opt. Soc. Amer. **2**: 93–96. 1919. (Geophysical Lab. Papers on Optical Glass, No. 22*b*.)

In this paper is considered the quantitative effect of external and internal reflections on the intensity of light-waves transmitted by the calcite rhomb and the Wollaston prism, when these are used in photometric work. This discussion is necessary to an adequate understanding of polarization photometers and the factors underlying their use. F. E. W.

GEOLOGY.—*The future of Alaska mining.* ALFRED H. BROOKS. U. S. Geol. Survey Bull. **714-A**. Pp. 56, pls. 3, fig. 1.

Although many local factors affect the future of Alaska mining, the most important consists of the mineral reserves. An estimate of Alaska's mineral reserves would be difficult enough, even with complete geologic maps. Only twenty per cent of the Territory has been covered by even reconnaissance geologic surveys, and less than one per cent by detailed surveys. The information at hand does not permit of even approximate quantitative estimates of reserves. It indicates, however, the areal distribution of the mineral deposits and a study of their geologic occurrence gives a basis for forecasting their availability to the miner.

The wide distribution of placer gold in Alaska and the known occurrence of many gold-bearing quartz veins shows the large areal extent of the auriferous mineralization. Furthermore, the wide distribution of intrusive granites, with which the occurrence of gold is genetically related, augurs well for future discoveries. The Alaska placers have during 40 years of mining produced $218,000,000 worth of gold. A careful consideration of all the facts available indicates that the placer gold reserves have a value of at least $360,000,000.

The Alaska copper deposits are widespread and are found in a number of different modes of occurrence and geologic relations. It is important to note that the Alaska copper deposits thus far developed are primary. The practical deduction from these facts is that no greater variation in the mineral

composition and copper content of the ores is to be expected at depths to be reached by future mining than has already been noted a few feet below the surface. Alaska has produced a total of 272,500 tons of copper.

The Alaska coal reserves include enormous quantities of lignite, considerable low-grade bituminous coal, and much smaller quantities of high-grade bituminous coal and anthracite. There are many other potential mineral deposits in Alaska in addition to those listed above. Of these, the petroleum fields give the most promise for immediate development. Between 1880 and 1919 Alaska produced mineral wealth to a total value of $438,160,000. A. H. B.

ZOOLOGY.—*The Echinoderms of the Canadian Arctic Expedition, 1913–18.* AUSTIN H. CLARK. Rep. Canadian Arctic Exped. 1913–18, Vol. **8**, Part C, Echinoderms. Pp. 11 (1C-11C).

The echinoderms, 2024 specimens representing 20 species, secured by the Canadian Arctic Expedition, are herein described and the relationships of the Canadian Arctic fauna are discussed. A. H. C.

ZOOLOGY.—*Additional data for the Report on Echinoderms of the Canadian Arctic Expedition, based upon specimens from the "Neptune" and other Eastern Arctic Expeditions.* A. H. CLARK. Rep. Canadian Arctic Exped. 1913–18, Vol. **8**, Part C, Echinoderms. Pp. 3 (11C–13C).

Herein is recorded additional arctic material in the collections of the Victoria Memorial Museum at Ottawa. A. H. C.

ZOOLOGY.—*Sea-Lilies and Feather-Stars.* AUSTIN H. CLARK. Smithsonian Misc. Coll. **72**, No. 7, 1–43, pls. 1–16. 1921.

This is a semi-popular summary of the present-day knowledge in regard to living crinoids; it includes a considerable amount of hitherto unpublished information, especially concerning the color of these animals, the extraordinary similarity between crinoids and plants, and the conditions of parasitism under which crinoids live. A. H. C.

PROCEEDINGS OF THE ACADEMY AND AFFILIATED SOCIETIES

PHILOSOPHICAL SOCIETY

846TH MEETING

The 846TH meeting was held in the assembly hall of the Cosmos Club on February 12, 1921. The meeting was called to order by President FARIS with 66 persons present. The following program was given:

C. LEROY MEISINGER: *The meteorological factor in aeronautics* (illustrated).

For various reasons the public confidence, the essential factor in business success, has not been acquired in commercial aeronautics, and it behooves enterprises engaged in promoting civil aviation to take advantage of every agency which will help in this direction. Meteorology is such an agency and its application to aeronautics is two-fold: climatological, dealing with average conditions of the elements; and current, dealing with conditions prevailing at the time of flight.

The functions of the Weather Bureau in relation to aeronautics are (1) to collect and disseminate observational data; (2) to forecast for specified regions; and (3) to conduct researches. The limitations of the work of the governmental agency are expected to evolve the aeronautical meteorologist, privately retained by commercial concerns. His duties will consist

in (1) the interpretation and detailing of information for specific craft in flight; (2) the dispatching of craft; (3) the furnishing of information to other departments of the concern; and (4) the instruction of pilots.

Governmental activities must be expanded along lines of the collection of aerological information. With this assistance, the general flying weather forecasts will probably keep pace with the development of the demand. The making of upper air pressure maps is the type of research problem of great assistance in forecasting. The status of this problem was discussed. The work of the commercial meteorologist can be surmised by reference to charts of upper air conditions along flying routes. This paper has appeared in full in the *Monthly Weather Review*.

L. H. ADAMS and E. D. WILLIAMSON: *The density of strained glass* (illustrated; presented by Mr. Adams.)

The stresses existing in "strained" glass are such that in the interior portion of the glass the density is less than that of unstrained (annealed) glass, while in the outer portion it is greater. It can be demonstrated, however, that in any strained piece of glass these two effects exactly neutralize each other, so that the total volume of the piece is unaffected by strain. In order to reconcile this conclusion with the experimental results which always show a smaller density for strained glass when compared with unstrained glass, it is necessary to assume that the apparent diminution of density is due to the formation of bubbles in the interior, where a hydrostatic negative pressure exists. This agrees with the conclusion reached many years ago by Barus that the low density of Prince Rupert's drops is a consequence of the presence of *vacuum* bubbles.

G. T. RUDE: *The tidal work of the Coast and Geodetic Survey* (illustrated).

Tidal work of the Coast and Geodetic Survey had its origin in the necessity for reducing soundings, in hydrographic surveys, for the fall and rise of the tides. The needs of the engineer and mariner have necessitated the extension of the work until now it covers the following fields: Prediction of tides and preparation of annual tide tables; determination of datum planes; development of instruments for observing and predicting tides; study of mean sea level and its relation to crustal movements; and the study of tidal phenomena in general.

The issue of tide tables for the use of the mariner began in 1853 with a condensed table for eight stations for the United States. These tables have increased in size and scope so that now they appear annually, in advance, as a volume of about five hundred pages covering the entire maritime world, with full predictions for each day of the year at eighty-one principal ports and tidal differences for more than thirty-five hundred subsidiary ports.

Prior to 1882 the tides were predicted by means of empirical tables and graphs. Beginning with that year the predictions were made on a machine designed by Mr. William Ferrel of the Survey. This machine was essentially a maxima and minima machine and in 1910 it was replaced by a new tide-predicting machine designed and constructed in the office of the Survey. On this new machine the height of the tide at any time between high water and low water is indicated, and the time and height of the tide are indicated on the face of the machine, from which they can be recorded directly on forms for the printer. The setting of the machine and the prediction of tides for a full year at any station require about ten hours.

It is, of course, out of the question to predict the tides for all ports. To

secure the state of the tide at places where no predictions are made, it is customary to refer such places to some port for which predictions are made. The referring of a subsidiary port to the proper standard port has led to a study of the different types of tides, the principal ones of which are the semi-daily, the daily and the mixed. In the semi-daily tide we have two high and two low waters every day, with morning and afternoon tides very much alike. In the daily tide we have only one high and one low water a day. In the mixed type of tide, caused by a combination of the two preceding types, we have two low and two high waters a day, but with differences in duration and height of morning and afternoon tides.

In all types of tides we find a variation with the moon's declination. When the declination is small, the forces giving rise to the daily wave are small, and at such times we may have semi-daily tides even at places where the daily is the predominating type. When the declination of the moon is large the daily forces are at a maximum, and we will have even in the semi-daily tide a difference between the morning and afternoon tides.

Formerly surveyors and engineers made use of arbitrary or local datum planes. To eliminate the confusion resulting from this practice, which frequently made it impossible to correlate the results of recent with the previous surveys, the Coast and Geodetic Survey has been establishing datum planes, based on tidal definition, for the coasts of the United States. The great advantage of the tidal datum plane lies, not only in its simplicity of definition, but also in the certainty with which it may be reestablished at any future time.

For practical purposes a tidal plane determined from a series of observations covering a period of a month may be considered as well determined. However, such planes determined at different times may differ considerably, and for the accurate determination, it is necessary to have long-continued observations at selected representative points. At these principal stations the Survey maintains self-registering tide gauges, which automatically record the height of the tide. Such observations covering a number of years bring out changes in mean sea level and furnish the data for a quantitative determination of relative changes in elevation of land and water.

The space allotted permits the covering of only the practical phases of the tidal work of the Survey as they relate to the needs of the engineer and mariner. The theoretical phases, however, as they relate to the development of the theory of tides, have not been neglected. The tidal papers of William Ferrel and R. A. Harris were results of the Survey's tidal studies along these lines.

The first paper was discussed by Messrs. SOSMAN, LLOYD and HUMPHREYS.

D. L. HAZARD, *Corresponding Secretary.*

847TH MEETING

The 847th meeting was held in the assembly hall of the Cosmos Club on February 26, 1921. The meeting was called to order by President FARIS with 41 persons present. The program was as follows:

F. HASTINGS SMYTH and HOWARD S. ROBERTS: *The system cupric oxide cuprous oxide, oxygen,* (illustrated; presented by Mr. Smyth).

This system has been studied by several investigators, notably by FOOTE and SMITH, and L. WÖHLER has argued rather convincingly that a continuous series of solid solutions exists between the two copper oxides, and that at

any given temperature the oxygen equilibrium pressure is dependent on the composition of the solid phase.

The authors' results show that solid solutions are absent, and that the following reactions may take place in the system:

(1) $4CuO(s) \rightleftharpoons 2Cu_2O(s) + O_2(g) - \Delta H_1$

(2) $4CuO(s) \rightleftharpoons 2Cu_2O(l \text{ solution in } CuO) + O_2(g) - \Delta H_2$

(3) $4CuO(l \text{ solution in } Cu_2O) \rightleftharpoons 2Cu_2O\ (s) + O_2(g) - \Delta H_3$ where ΔH_1, ΔH_2, and ΔH_3 are the heat quantities absorbed in each reaction.

At 1080.2°C and an oxygen equilibrium pressure of 402.3 mm. Hg, a eutectic containing 72.7 mol per cent Cu_2O and 27.3 mol per cent CuO fuses. Below this point, therefore, Reaction (1) takes place; above this point either Reaction (2) or (3) takes place, dependent upon the quantity of oxygen originally present in the solid and liquid phases. The pressure-temperature curves for these reactions have been traced experimentally up to temperatures of 1085.0°, a metastable point, for Reaction (1); to 1232.5° for Reaction (2); to 1231.3° for Reaction (3).

Theoretically the course of these curves, which intersect at the quadruple (eutectic) point of the system can be followed by means of the general equation

$$dp/dt = \Delta n/\Delta v$$

which, under conditions of constant temperature and pressure, becomes

$$dp/dt = 1/T.\Delta H/\Delta V$$

ΔH_1 remains substantially constant over the temperature range studied. ΔH_2 can be considered as the algebraic sum of ΔH_1 and of additional heat absorbed by fusion of Cu_2O and of additional CuO to form the liquid solution. ΔH_2 is therefore greater than ΔH_1 and the value of dp/dt above the eutectic point is always greater than that of the extrapolation of curve for Reaction (1). Likewise ΔH_3 is always less than ΔH_1 and the slope of the curve for Reaction (3) is always less than that of the extrapolation of the curve for Reaction (1).

The curve for Reaction (2) is tangent to the curve for the condensed system $CuO(s)$, $CuO(l)$ at the melting point of pure CuO; that for Reaction (3) is tangent to the curve for the system $Cu_2O(s)$, $Cu_2O(l)$ at the melting point of Cu_2O. The melting point of pure CuO has not been reached.

The melting-point diagram for mixtures of the two copper oxides, under equilibrium pressures of oxygen, has been established throughout the range 94.4 mol per cent Cu_2O to 45.9 mol per cent Cu_2O.

Lower equilibrium pressures were determined in a fused silica tube reaction chamber with a mercury manometer attached. Higher pressures were determined with a furnace enclosed in a brass bomb, and with a calibrated Bourdon gage. Temperatures were measured by means of a platinum-platinrhodium thermoelement. Purified electrolytic oxygen was used and copper oxides were prepared from previously analyzed chemically pure metallic copper.

The paper was discussed by W. P. WHITE.

F. WENNER, J. S. MARTIN, and NYNA L. FORMAN: *The electrical resistance of the human body.* (Illustrated; presented by Mr. Wenner).

Measurements of the electrical resistance of the human body have given results differing among themselves so radically that one seeking information on the subject is led to question either the reliability of the work or the significance of the values given.

The difficulties encountered have had their origin mainly in those portions

of the skin through which the test current entered and left the body. The skin not only has a high and uncertain resistance, but in it there are capacity, polarization, and possibly other effects which not only make the measurements difficult but largely destroy their significance. It seemed, therefore, that it might be of interest to measure the resistance of some parts of the body not including those portions of the skin through which the test current enters and leaves. To thus limit the parts whose resistance is to be measured, use is made of four connections to the body. Two of these serve to lead the test current to and from the body and two serve to bring the potential difference developed in a particular part of the body, as a result of the test current, to a place where it can be measured.

Ordinarily we understand the resistance of a conductor to be the ratio of the drop in potential in it to the current flowing. However, when a conductor has four terminals to which electrical connections can be made, the resistance is understood to be the ratio of the drop in potential between the potential terminals to the current entering and leaving through the current terminals. In either case the potential considered should be only that caused by the current and not that which may arise in some other way.

In some of the measurements the left hand and the left foot were used as a pair of current terminals, and the right hand and right foot as a pair of potential terminals. Electrical connections to the hands and feet were made by placing them in vessels containing a solution of common salt in water. These vessels are either lined with metal, or contain a piece of metal having a fairly large surface. Insulated wires are attached to the pieces of metal or to the metal lining and serve as leads for connecting the body into the circuits used in making the measurements. The resistance of the four-terminal conductor formed in this way is substantially the resistance of the trunk of the body with all the connecting resistances and practically all disturbing influences eliminated.

In most cases the resistance has been found to be between 20 and 30 ohms.

The paper was discussed by Messrs. SILSBEE, WHITE, C. A. BRIGGS, and others.

H. H. KIMBALL, *Recording Secretary.*

SCIENTIFIC NOTES AND NEWS

The following officers were elected at the annual meeting of the Maryland-Virginia-District of Columbia Section of the Mathematical Association of America, held at the drafting hall of the Capitol on May 7: *President*, OSCAR S. ADAMS of the Coast and Geodetic Survey; *Secretary-Treasurer*, G. R. CLEMENTS of the U. S. Naval Academy, Annapolis; *Member Executive Committee*, F. D. MURNAGHAN of Johns Hopkins University, Baltimore.

The National Geographic Society is sending an expedition this summer to explore and study the Pueblo Bonito and Pueblo del Arroyo ruins in the Chaco Canyon of northwestern New Mexico. The expedition will be led by Mr. NEIL M. JUDD of the U. S. National Museum.

Recent accessions in the Division of Plants of the National Museum include 400 specimens from China and New Caledonia, received as an exchange from Mr. G. BONATI of Lure, France; 250 specimens of Chinese plants, collected by SIMEON TEN, purchased from the Arnold Arboretum in Boston; and 713 specimens from Quebec, received as an exchange from the College de Longueuil.

The semi-annual meeting of the Advisory Committee on Non-Ferrous Alloys was held at the Bureau of Standards on April 20 and was attended by members of the various technical societies representing the non-ferrous industries and also by representatives from the technical services of the War and Navy Departments. The subjects discussed included specifications for hard-drawn brass wire for airplane bomb release, rotating bands for projectiles, various aircraft problems related to aluminum alloys, questions concerning the composition of bearing metals, corrosion and etching of metals, and the part played by gases in metals.

The new Low Temperature Laboratory of the Bureau of Mines was dedicated by Madame CURIE at 10 a.m. on Saturday, May 21.

The National Screw Thread Commission met at the Bureau of Standards on Monday, April 18, and considered the Progress Report recently issued and outlined a program for continuing the work of the Commission.

Messrs. L. H. ADAMS and E. D. WILLIAMSON of the Geophysical Laboratory, Carnegie Institution of Washington, have received the Longstreth Medal from the Franklin Institute of Philadelphia in recognition of their work on the annealing of glass.

Dr. C. F. BROOKS, meteorologist at the Weather Bureau and editor of the *Monthly Weather Review*, has resigned, effective June 30, to accept the associate professorship of meteorology and climatology at Clark University, Worcester, Massachusetts.

Mr. F. C. BROWN of the Bureau of Standards returned in May from a two months' trip to the scientific institutions of England, France, and Germany.

A meeting in honor of Madame CURIE was held at the National Museum on Friday evening, May 20. Dr. ROBERT A. MILLIKAN of the University of Chicago lectured on *Radium*.

Dr. FREDERICK B. POWER, of the Bureau of Chemistry, was presented with a gold medal by Mr. HENRY S. WELLCOME, founder of the Wellcome Chemical Research Laboratories of London, "in commemoration of his eighteen and one-half years of service as Director of the Laboratories and in recognition of his many valuable researches in the field of organic chemistry." The presentation took place at the Cosmos Club on May 9.

Dr. EDWARD BENNETT ROSA, chief physicist of the Bureau of Standards, died suddenly in his office at the Bureau on May 17, 1921, in his sixtieth year. Dr. Rosa was born at Rogersville, New York, October 4, 1861. After graduation at Wesleyan and Johns Hopkins Universities, he became instructor at the University of Wisconsin, and then professor of physics at Wesleyan. He was appointed chief physicist of the Bureau in 1901. At Wesleyan he developed the physical side of the respiration calorimeter with W. O. ATWATER. At the Bureau his attention was directed to the determination of the fundamental electrical units and constants, including the ampere and the electromagnetic-electrostatic ratio, and also to numerous engineering problems, particularly during the War. During the past three years he had devoted much thought and labor to the problem of the Federal Government's scientific personnel and its reclassification by Congress, and his papers on this subject, first published in this JOURNAL[1] and widely reprinted, have focussed much public attention upon this important matter. He was a member of the ACADEMY and the Philosophical Society of Washington, as well as of many national scientific and technical organizations.

[1] This JOURNAL **10**: 341–382, 533–558. 1920.